Coleman, Charles

From: Dan Tabish <dan@inlandmet.com>
Sent: Tuesday, September 15, 2015 10:41 AM
To: Coleman, Charles
Cc: Rick Tabish
Subject: Anaconda Project Executive Summary
Attachments: Grant Executive Summary.pdf

Good Morning Charlie:

Attached you will find a file containing a well-written Executive Summary of the Anaconda Slag Project that was submitted by our team at MT Tech. It was one of the documents in a grant application that was submitted to the MT State Board of Research and Commercialization Technology (MBRCT).

Please let me know if you need any additional information.

Thank you.

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RECOVERY OF VALUABLE PRODUCT STREAMS FROM WASTE COPPER-SMELTER SLAG

EXECUTIVE SUMMARY

a) Description of the proposal

Montana Tech, working with Basin Industrial Services located in Missoula, seeks funding for applied research to develop and demonstrate promising methods for processing the Atlantic Richfield Company (ARCO) slag pile located in Anaconda, MT into two product streams: metals for steel making and proppant for hydraulic fracturing. The objectives are:

1. To optimize a process to simultaneously separate and recover iron, copper, silica, and alumina from the waste slags at Anaconda.
2. To demonstrate that two types of valuable and marketable products can be produced cost effectively from the slag—namely pig iron for steelmaking and other uses; and proppant for hydraulic fracturing to enhance oil and gas production.
3. To obtain key parameters for designing a small pilot-scale demonstration set-up for converting Anaconda slag to marketable metal and proppant.

b) Explanation of the technology involved

Waste copper smelting slag typically contains 0.77% to 1.32% copper, about 40% iron, about 35% silica, and minor amounts of other metallic elements, such as molybdenum, zinc, lead, and arsenic. It is considered to be a hazardous material due to the presence of toxic substances, posing a risk to human health and the environment. The proposed technology has the potential to recover marketable products at modest cost from the waste slag. Specifically, this project proposes to develop and demonstrate a carbothermal reduction process to recover Fe and Cu metals and atomize the residual glass slag to produce proppant materials in high demand in the oil industry for hydraulic fracturing-enhanced oil and gas production.

Proppant is used in the process of hydraulic fracturing of oil and gas wells to hold open fractures induced in the reservoir rock during the stimulation. A slurry of water, small amounts of additives and sand-like proppant is injected at high-pressure and flow rates to create the fractures. On flowback, the proppant remains in the fracture, holding it open and creating a permeable channel for hydrocarbons to flow more easily.

Initial efforts at producing proppant from the slag material have included disk atomization methods. Other methods, including wet-forming and sintering of the material could be evaluated. This latter method is currently in use for manufacturing high-value man-made ceramic proppants.

c) Description of any new products or processes that might be developed

A new process for recycling copper-smelting slag by using carbothermal reduction-atomization is proposed to be developed. This process will produce two new product streams: a Fe-Cu alloy and a

proppant. Thus, the process would transform the waste slag into marketable products. Not only will the process benefit two industries: steel making and hydraulic fracturing; it will also have tremendous benefit to the environment by making it feasible to diminish the slag pile in Anaconda and employ Montanans in a future plant.

d) Explanation of why the proposal is important and should be funded

The waste slag from copper smelting in Anaconda contains significant amounts of valuable metals and toxic substances. The process that would be developed would eliminate these huge amounts of toxic substances, thereby benefitting soil, groundwater, the environment and human health. Simultaneously, valuables in the waste slag, such as Cu, Fe, and Si, will be recycled into useful products for which there are significant markets. The production-scale effort will obviously employ Montanans at the plant that would be built if the process is successful. Thus, a carbothermal reduction-atomization method of recovering of the iron, copper, and silica in the waste slags would both reduce environmental contamination and produce value-added product streams, namely metal and proppant material.

The proppant industry is large and growing. It is estimated that this market could grow to $19 billion by 2019. Construction costs are about $10 million for a typical well in the Bakken in eastern Montana. It is common for proppant to make up about 10% of that cost or about $1 million for 2 to 3 million pounds (1000 to 1500 tons) of proppant. And nearly half of that cost is for transportation of the material. If successful, the proppant produced here in Montana will have a significant cost advantage over other sources simply because of the reduction in transportation costs. While efforts to locate local sources are on-going, there is currently no proppant being produced within Montana.

2. An explanation of how the project meets each of the following statutory project criteria:

a) Has potential to diversify or add value to a traditional basic industry of the state's economy

The slag pile in Anaconda accumulated over a century during copper-mining—a traditional, basic Montana industry. The slag pile has not been fully remediated, and it represents a huge volume of material of environmental and health concern. The ability to reprocess the ARCO slag will provide useful, revenue-generating product streams, while simultaneously reducing the slag volume and the associated environmental and health risks. The diversification includes the production of proppant material in addition to metals.

b) Shows promise for enhancing technology-based sectors of Montana's economy or for the commercial development of discoveries

The estimated 30 million cubic yards of slag (2) can provide years' worth of source material/feedstock to supply a new processing plant. For every ton of Anaconda slag that would be processed, approximately 400 pounds of pig iron and 1300 pounds of glassy proppant could be produced. A 10-furnace production facility processing approximately 700 tons of Anaconda slag per day would be capable of producing 140 tons of pig iron and 455 tons of proppant per day. At conservative selling prices, these output rates could generate over $20 million in pig iron sales per year and over $80 million in proppant sales per year—more than sufficient for profitability.

c) Employs or otherwise takes advantage of existing research and commercialization strengths within the state's public university system and private research establishment

This project takes advantage of research and commercialization strengths of Montana Tech, which has developed significant expertise in both areas critical to the success of this project: mineral and metallurgical processing and proppants. Montana Tech's Center for Advanced Mineral and Metallurgical Processing (CAMP and the Department of Metallurgical and Materials Engineering (M&ME) possess both expertise and commercialization capabilities in these areas. The closely associated Proppant Research Group is expert in evaluating materials for proppants. It is currently completing a project for the Montana Board of Oil and Gas Conservation (MBOGC) titled "SNaP: Survey of Native Proppant" which seeks to evaluate the potential of geologic formations in Montana to serve as source rock for sand proppants. Through this funded project, the infrastructure is in place for the proppant development portion of this proposal.

d) Involves a realistic and achievable research project design

Preliminary technical work has been completed, showing considerable promise. Preliminary reduction tests on Anaconda's waste slag have proved that Fe-Cu alloy can be obtained with reduction of slag by carbon. The molten glass 'wastes' in the reduction experiment can be atomized into proppant-like material. Preliminary testing of the proppant portion of the product stream is encouraging. The lab-scale quantities of the material produced so far show a much higher level of the desirable sphericity than natural materials. The strength is only slightly lower than that of sand products, and within the range required for proppant. It is expected that the research and development effort to develop the process by optimizing the chemistry and process conditions can improve these results to make the glassy material even more competitive. The project design builds on these positive, preliminary results.

e) Develops or employs an innovative technology

The idea of converting waste slag into metals and proppant materials is innovative. A novel combination of carbothermal reduction and atomization methods would be developed to simultaneously recover marketable iron, copper, and silica glass from the waste slag pile in Anaconda.

f) Is located in Montana

The ARCO slag pile is located in Anaconda, MT and the future processing plant would also be located in that area. The research and development effort will be conducted at Montana Tech in Butte.

g) The research team possesses sufficient expertise in the appropriate technology area to complete the research objective

This interdisciplinary project would be managed and integrated by Montana Tech's Center for Advanced Mineral and Metallurgical Processing (CAMP)—a center of excellence in materials research and industrial/commercial process development, support, and troubleshooting.

Professor Courtney Young of the Metallurgical and Materials Engineering Department (M&ME), co-located with CAMP, would lead the effort to demonstrate and optimize the recovery of valuable metals from waste slag, using a reduction process. Young has numerous years of metallurgical waste treatment and extractive metallurgy experience, for which he is internationally recognized. Dr. Guojun Ma is a

visiting researcher at Montana Tech, who brings 13 years of experience in South Africa and China on the recovery of metallurgical wastes with pyrometallurgical methods.

John Getty of the Geophysical Engineering Department was the primary driver behind the formation of the Proppant Research Group at Montana Tech. Over the past 6 years he has developed a national and international reputation in the evaluation of natural and manmade proppant materials, and he has been actively involved in the research and development of novel materials for this application.

Ronda Coguill, Materials Testing Manager at CAMP, would manage and support the materials testing and characterization activities. She has several years of experience in materials testing and industry support, both at Montana Tech/CAMP and previously at the University of Wyoming.

h) Has received financial support based on its scientific merits following review by a recognized federal agency, philanthropic foundation, or other private funding source

A precursor project to this one has received financial support, based on its scientific merits. The SNaP project is a $380,000 three-year collaborative effort, led by John Getty. This project involves the Geophysical Engineering Department, the Petroleum Engineering Department, and the Montana Bureau of Mines and Geology, co-located on the Tech campus. It was funded by a grant from the MBOGC. This proposal is the first one addressing the conversion of Anaconda slag to marketable metal and proppant product streams, and it has not received previous financial support.

i) Includes research opportunities for students

This project will engage at least one undergraduate and one graduate student from the Metallurgy Department in the metals product work. At least two undergraduates will be involved in the proppant evaluation.

3. **This project is not in the areas of Clean Coal or Renewable Resources.**
4. **This project is applied research.**
5. **Matching funds of $29,194 are currently available.**
6. **Total financing needs for this 12-month phase of the effort is $110,990.**
7. **Request from MBRCT: $81,797.**
8. **An external peer review of this specific project has not yet been conducted.**